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Sediment and plankton lift off recirculations in strong synthetic turbulence (KS)

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The study of particle diffusion and of turbulent sedimentation is of great importance in many geophysical fields, such as in Environmental Science or Oceanography as well as in Bio-environmental and industrial processes. For a long time, the study of diffusion was numerically computed with random free paths, which gives Brownian behavior. (Richardson 1929).
These stochastics methods have the objection that do not take into account the flow profile. On the other hand, there are many ways to simulate a fluid flow, but when this is turbulent our aim is to simulate the behaviour of neutral or heavy and inertial particles of biological or geological nature in a turbulent flow, in a simple way with a kinematically simulated model and to validate the results. We use the Kinematic Simulation (KS) model, also known as Synthetic Turbulence, suggested by Kraichnan (1966) and developed further by Castilla et al.(2007), Nicolleau et al.(2012).

In this model, velocity field is generated through a Fourier series of random modes. The typical scales and the energy spectrum of the turbulence are inputs of the model. As we do not solve the flow in a discrete grid, but use a random predictive expression, we can simulate the flow at the smallest scales. In an unstratified flow, a KS flow field consists of a random, truncated Fourier representation in space and time, subject to constraints associated with incompressibility, and a prescribed initial energy spectrum. For stratified calculations, two further constraints are imposed, associated with the internal wave field in stratified flows, and the tendency of density variations to suppress vertical motion. With these model modifications, good agreement is found between KS and DNS with regard to the confinement in the vertical direction characteristic of stratified turbulence. Since stratifed flows exhibit this vertical confinement, KS in strictly two dimensions was considered as a first step to understanding dispersion within a stratified flow. The properties of ensemble averages of the separation between two particles in a 2D turbulent flow were considered, and the KS approach was found to give satisfactory answers, with good comparison to experiment. We also compare structure and intermittency between KS and DNS. And experiments (Redondo 1988)

The dynamical processes associated with the stably stratified atmospheric boundary layer or in the ocean thermocline are less well understood than those of its convective counterparts. This is due to its complexity, and the fact that buoyancy reduces entrainment across density interfaces. We present results on a numerical simulation of homogeneous and density stratified fluids and of comparable laboratory experiments where a sharp density interface generated by either salt concentration or heat, advances due to grid stirred turbulence Redondo (1988, 1990).

The appearance of bursts of turbulence in very stable conditions due to breaking up of the internal waves, confers a sporadic character to the turbulence; these conditions of non-fully developed turbulence could explain this unusual behaviour of the scaling exponents. (Mahjoub et al. 1998, 20009

The structure functions show, in the inertial range, a potential law . The relation is concave in strong mixing situations (instability with fully developed turbulence), and convex in very stable situations (in which the breaking up of the interval waves confers a sporadic character to the turbulence).The multifractal model can not be used to represent situations of non-fully developed turbulence but the use of structure function analysis allows the investigation of intermittent and scale to scale energy transfer even in local non equilibrium flows. The relative diffusion of tracers is strongly dependent on the slope of the energy spectra which tends to Richardson's law also for very steep spectra. (Castilla et al. 2007)

Local turbulence is used to establish the geometry of the turbulence mixing, changes in the equilibrium (or not) cascade may lead to more physically realistic (and understandable) models to paramerize sub-grid scaling. Care has to be taken when interpreting the direct 3D Kolmogorov cascade and the Inverse 2D Kraichnan Cascade. It is very interesting to use ESS and the third order structure functions (p=3) to investigate the scale to scale transfer of energy (and enstrophy)

A parameter space based on Richardson numbers, Rossby numbers and Reynolds Numbers can be used to determine the dominant instability with different intermittencies in a complex full stratified-rotating flow. Intermittency diminishes as spectral slope increases between 5/3 (Kolmogorov's local energy balance) and 3 (Kraichnan's local enstrophy balance) like near a boundary. (Rodriguez et al 1999, Redondo et al. 1993)(Gabaldon and Redondo 2001)

Helicity local balance leads to a 7/3 Energy spectra that may be strongly affected by intermittency. It should also depend on the length scale. So in K62, Kolmogorov introduced the notion of intermittency, and he would transpose the universality character of his previous constant to the universality of several parameters, the intermittence which is generalized to higher orders p, μ(p). We know that μ is not universal, as it varies from approximately 0.2 to 0.7, according to different experiments. The new energy spectra, E(k,p), has a correction term in its power: -5/3 becomes $-5/3-\mu(p)/9$, thus, the global form of the spectra is E(k) $\sim$ k -β(p), The different simulations produce very different spatial distributions of the bio-tracers.

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